I also wish to observe on this occasion that the Percopsidæ, which are not included in Cope's synopsis and are placed in "Suborder uncertain" by Gill, are most nearly allied to the Salmonidæ. As in *Salmo*, the supraoccipital completely separates the parietals. Prof. Stewart, who has kindly examined bones of *Percopsis guttatus* and *Columbia transmontana* at my request, informs me that he has been unable to find a trace of lacunæ, although these are present in the bones of *Salmo*, *Coregonus*, *Thymallus*, *Stenodus*, *Microstoma*, and *Argentina*; he, however, finds them likewise absent in *Osmerus*, *Hypomesus*, *Retropinna*, *Salanx*, and *Plecoglossus*.

3. On certain Features in the Skull of *Osteoglossum formosum*. By Prof. T. W. Bridge, M.A.[1]

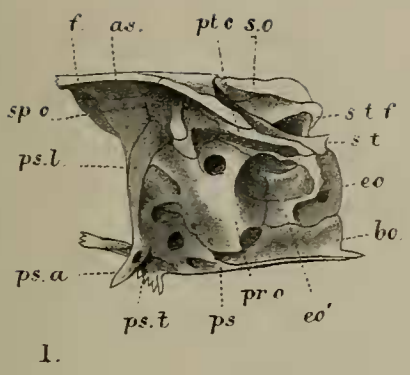
[Received March 28, 1895.]

(Plate XXII.)

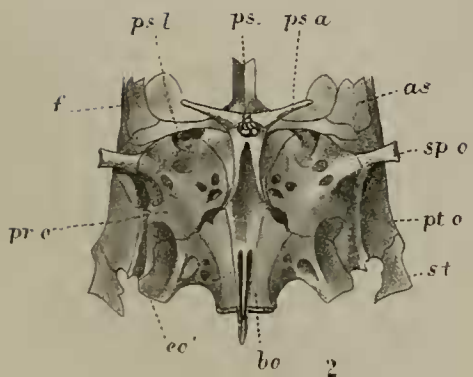
While recently examining a skeleton of a specimen of *Osteoglossum formosum*, Müll. et Schl., in the Zoological Museum of Mason College, I noticed one or two interesting features in connection with the skull which, so far as I have been able to discover, have not previously been described. The only reference to the skull with which I am acquainted is by Hyrtl in his "Beitrag zur Anatomie von *Heterotis ehrenbergii*, C.V." (Denkschr. d. Akad. Wiss. Wien, Bd. viii. 1854, pp. 73–88). In this paper the author briefly compares the skeleton of *Osteoglossum* with that of *Heterotis*; but although the comparison extends to certain features in the structure of the skull in the two genera, Hyrtl makes no reference whatever to those structural modifications in the skull of *Osteoglossum* to which I desire to direct attention.

On examining the base of the skull of *Osteoglossum formosum* the parasphenoid (Pl. XXII. figs. 1 and 2, *ps.*) is seen occupying its normal position, firmly attached to the ventral surface of the basioccipital behind, and, from that point, extending forwards beneath the cartilaginous interorbital region to its junction with the dentigerous vomers anteriorly. As the parasphenoid passes between and beneath the two prootic bones it forms the floor of a median canal for the muscles of the eyeball, the roof of which is, as usual, formed by the mesial union of the two prootics in the floor of the cranial cavity. At this point the parasphenoid gives off from its lateral margins two well-marked processes on each side: first, an ascending process (*ps.l.*) which passes obliquely upwards, in contact with the anterior margin of the prootic of its side, and finally terminates above by overlapping the outer surfaces of the prootic (*pr.o.*), the sphenotic (*sp.o.*), and the

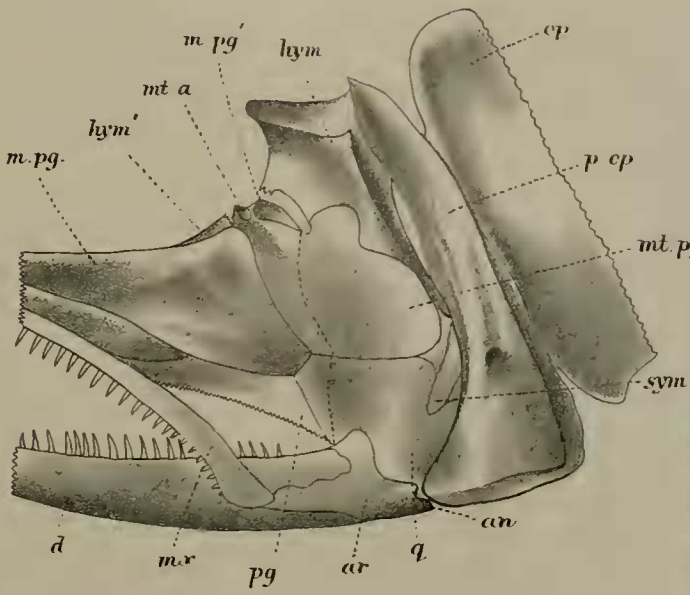
[1] Communicated by Dr. Günther, F.R.S.



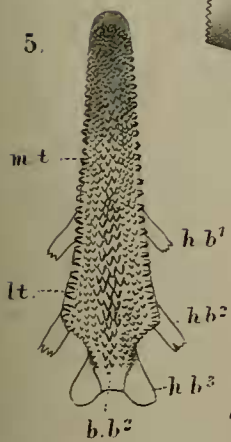
1.



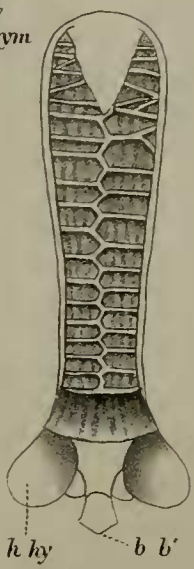
2.



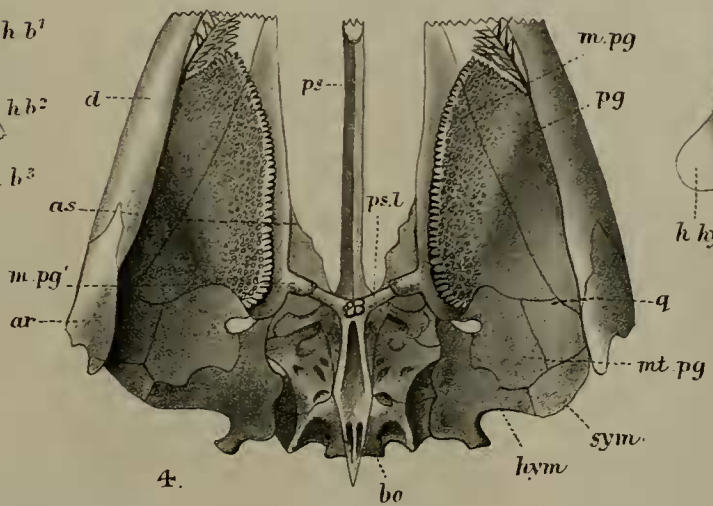
3.



5.



6.



4.

F W Crispe del. ad nat. P. Smit lith. Mintern Bros. imp.

SKULL OF OSTEOGLOSSUM FORMOSUM.

alisphenoid (*as.*) bones at the point where the three are in sutural connection with one another near the antero-superior angle of the auditory capsule (fig. 1). This process is, undoubtedly, the equivalent of the conspicuous ascending or lateral process of the parasphenoid in certain Ganoids, which it also closely resembles in its extensive relations to the anterior wall of the auditory capsule, and, more particularly, in its extension so far dorsally as to overlap the sphenotic region—an extension which, so far as I am aware, has no parallel in any other Teleost, although characteristic of such Ganoids as *Acipenser*, *Polypterus*, and *Amia*. The second of the two processes (figs. 1 and 2, *ps.a.*) is about 13 mm. in length and grows out on either side from the lateral margin of the parasphenoid, immediately ventrad to the root of the ascending process, and tapers to a free distal extremity. The process is horizontally disposed, at right angles to the long axis of the parasphenoid, or, at any rate, has but a very slight upward inclination from its root outwards, and is furnished with smooth rounded surfaces. This process may be termed the articular process of the parasphenoid. Midway between the roots of the two articular processes, and projecting downwards from the ventral surface of the parasphenoid, there is a mesially situated tubercle of bone (fig. 1, *ps.t.*) which supports a small cluster of teeth. These are small but variable in size, conical in shape, with pointed crowns, and so arranged that the two largest teeth occupy the hinder margin of the cluster, while about six smaller teeth are closely grouped together immediately in front of them.

The formation of special articular processes in connection with the parasphenoid is correlated with certain modifications in the mandibular arch, whereby the latter acquires a special articular connection with the former. The metapterygoid (figs. 3 and 4, *mt.pg.*) occupies its normal position as the proximal element of the arch. Posteriorly, the bone overlaps the external surface of the inferior half of the hyomandibular (*hym.*) and the contiguous outer surface of the symplectic (*sym.*); anteriorly, the metapterygoid is, in turn, overlapped on its inner surface by the mesopterygoid (*m.pg.*), while inferiorly it is firmly articulated to the superior margin of the quadrate (*q.*). The mesopterygoid (fig. 3, *m.pg.*) is the largest of the palato-pterygoid series, of which it forms the upper two-thirds. It is somewhat triangular in shape, the apex being directed anteriorly towards the palatine region, while the wider posterior portion overlaps the inner surfaces of the metapterygoid and quadrate bones. Inferiorly, the bone is firmly united to the pterygoid (*pg.*) throughout its entire length. The pterygoid (*pg.*) forms the inferior third of the palato-pterygoid series of bones, overlapping the inner surface of the quadrate behind, while externally, and for at least the anterior half of its length, it is rigidly attached to the inner surface of the dentigerous maxilla. A distinct palatine element is either non-existent or entirely cartilaginous, at any rate no trace of a palatine bone could be detected in the specimen examined.

As far as could be seen in the dried skull, the usual connection between the anterior extremity of the palato-pterygoid bar and the lateral ethmoid of its side must have been of a loose ligamentous character. Between the metapterygoid and the parasphenoid there is a singular articular connection. From the antero-superior angle of the metapterygoid a process (fig. 3, *mt.a.*) is bent inwards towards the base of the skull and lies in the horizontal plane. The anterior and posterior margins of the process are curved slightly upwards in such a way that the process forms a somewhat shallow, demi-cylindrical, articular surface, the concavity of which looks directly upwards. The mesopterygoid (figs. 3 and 4, *mp.g.*[1]), which, as already mentioned, overlaps the inner surface of the metapterygoid, is also bent horizontally inwards, but at its postero-superior angle, and, moreover, partially embraces the preceding process in such a way as to strengthen the floor and, at the same time, deepen the sides of the demi-cylinder. The hyomandibular also contributes to the formation of this curious articular surface. A process[2] from the anterior margin of the superior half of that bone (fig. 3, *hym.*[1]) is prolonged obliquely downwards and forwards, and, after blending with the anterior lip of the demi-cylinder, becomes applied to the adjacent upper margin of the mesopterygoid (*m.pg.*). It will be seen, therefore, that this process not only strengthens the anterior wall of the demi-cylinder, but, in addition, furnishes the latter with an incomplete roof. In the normal condition of these parts the articular processes of the parasphenoid fit into the two demi-cylindrical articular surfaces provided for them by the meta-pterygoids, in such a way, that a lateral sliding motion of the latter on the parasphenoid is possible.

In addition to the acutely-pointed teeth in the premaxillæ, maxillæ, and vomers, both the mesopterygoid and pterygoid bones carry teeth of variable size over nearly the whole extent of their inner or oral surfaces. The inferior border of the pterygoid (fig. 3, *pg.*) carries a series of small pointed teeth arranged parallel to the more externally situated and larger maxillary teeth (*mx.*). The rest of the inner surface of the bone (fig. 4, *pg.*) exhibits a granular appearance, from the presence of numerous, extremely fine, closely-set teeth. For the same reason the greater part of the oral surface of the mesopterygoid (*m.pg.*) has a very similar appearance, but, within a short distance of the superior margin of the bone, the fine denticles are replaced by a single longitudinally disposed row of much larger, conical, pointed teeth (fig. 4). Of these teeth the most posterior are the largest, and, moreover, are situated exactly opposite the mesial cluster of teeth in the parasphenoid; from this point forwards the teeth gradually but rapidly diminish in size. The teeth are slightly curved, and hence their pointed enamel-tipped crowns are directed obliquely inwards and a little downwards towards the corresponding teeth of the

[2] I am inclined to think that this process is not an actual extension of the hyomandibular, but, on the contrary, is really an ossified ligament.

opposite side of the oral cavity, instead of being at right angles to the surface of the mesopterygoid like the remaining teeth which this bone supports.

From this description it is apparent:—

i. That the various bones which form the proximal half of the mandibular arch and its palato-pterygoid bar are firmly rigidly connected with one another, and also with the corresponding elements of the hyoid arch—that is, with the hyomandibular and symplectic bones.

ii. That, in consequence of the articular connection of the hyomandibular with the periotic capsule, and the metapterygoids with the articular processes of the parasphenoid, combined with the looseness of the ethmo-palatine connection, the whole series of bones on each side are capable of a more or less extensive inward and outward movement, accompanied at the same time by the lateral contraction or expansion of the oral cavity. It is also clear that while the hyomandibular articulation with the skull and the nature of the ethmo-palatine connection will give the necessary mobility to the rigidly connected series of bones considered as a whole, the sliding character of the joint between the metapterygoids and the parasphenoid will give precision to such movements by strictly limiting them to the alternate approximation and separation of the bones of opposite sides of the head.

iii. That, as the result of such movements, the linear series of obliquely set teeth in the two mesopterygoids become opposable in the median line of the oral cavity, and, in conjunction with the mesial teeth in the parasphenoid, form part of an additional oral masticatory mechanism, distinct from the usual mechanism which is furnished by the upper and lower jaws and their teeth.

I have no knowledge of the character of the food of *Osteoglossum*, but, whatever may be its nature, it is evident that the food is subject to some kind of mastication in the oral cavity by the two parallel series of mesopterygoid teeth after its seizure in the first instance by the ordinary jaws. From this point of view there seems to be a fairly close analogy between *Osteoglossum* and the Crayfish, inasmuch as the relative functions of the mandibles and the gastric mill in the latter would seem to be performed by the ordinary jaws, and by the mesopterygoid and parasphenoidal teeth respectively in the former. In fact the analogy becomes even more precise if we consider that the relative position and relations of the mesopterygoid and parasphenoidal teeth in *Osteoglossum* are essentially similar to those of the zygocardiac and urocardiac teeth in the gastric mill of the Crustacean. It may be pointed out, however, that the two series of mesopterygoid teeth can scarcely come into actual contact in the median line of the oral cavity, but, on the other hand, it is certain that they can be brought so close together as readily to effect the crushing or more or less complete mastication of food which has been taken into the mouth.

In discussing the functions of the oral masticatory mechanism of *Osteoglossum* the singular dentigerous "tongue" of this fish,

and its functional relations to other parts of the mechanism, must not, however, be left out of consideration. This organ (fig. 5) is an elongated band-like structure, somewhat broader behind than in front, and consists of a continuous plate of tooth-bone confluent below with the upper surfaces of the large basihyal and the two most anterior of the basibranchial elements. The tooth-bone carries over the whole extent of its upper or oral surface an extensive series of closely-set teeth, the largest of which are arranged in three parallel longitudinal rows—a lateral series (*l.t.*) along each outer margin of the "tongue," and a mesial row (*m.t.*) along the centre. The lateral teeth, although somewhat smaller, are very similar in shape and disposition to the linear series in each mesopterygoid, and, like the latter, diminish in size from behind forwards; the central teeth, on the contrary, are smaller in size, obtusely conical in shape, and much less regularly arranged. Between the three principal series of "lingual" teeth the surface of the "tongue" has a granulated appearance from the presence of a number of minute, conical, closely-set teeth. In its natural position in the mouth the linear series of lateral teeth are vertically opposable to the corresponding series of mesopterygoid teeth, while the mesial series lie between and below the latter. It is probable, therefore, that all three series of teeth (viz. the mesopterygoid, the parasphenoidal, and the "lingual") co-operate in effecting the mastication of the food—the mesopterygoid teeth by means of their lateral motion in the horizontal plane, and the lingual teeth through their vertical movements, or possibly, but improbably, by a kind of rasping action.

The capacity for lateral movement on the part of certain of the oral bones is by no means peculiar to *Osteoglossum*. In the Pike (*Esox*), for example, and probably also in many other Teleosts, there can be no doubt that the proximal elements of the hyoid and mandibular arches and the various bones of the palato-pterygoid series are capable of similar movements as a more or less rigid whole, and that, in consequence, the jaw-system is similarly capable of lateral expansion and contraction. The capacity of the bones in question for lateral movement is no doubt of great service in widening the gape and thereby adapting the jaws for seizing relatively large prey, or it may be of considerable advantage in enabling the fish to firmly retain its possibly struggling prey in the oral cavity prior to the act of swallowing, or even in effectually aiding deglutition itself; but, at the same time, it is extremely doubtful if anything of the nature of oral mastication can be effected by these means. On the other hand, in none of the ordinary Teleosts is there any articulation between the metapterygoid and the base of the skull, and whatever lateral mobility the bones under discussion possess is entirely due to the nature of the hyomandibular-pterotic and the ethmo-palatine articulations. The special peculiarity of *Osteoglossum* lies in the fact that, while the jaws are capable of the same kind of lateral movement as in the Pike, there is, in addition, a secondary

articulation of the metapterygoid with the skull, the result of which is to give an altogether exceptional precision to such movements in accordance with the requirements of the highly specialized oral masticatory apparatus of this fish.

I am unable to say how far the possession of the mechanism is peculiar to *Osteoglossum formosum* among the Osteoglossidæ. It would certainly be interesting to ascertain whether it is restricted to this species, or is shared by either, or both, of the two remaining species of the genus, viz. *O. bicirrhosum* and *O. leichardti*; and also whether the mechanism is present in the sole remaining genera of the family, *Heterotis* and *Arapaima*.

It has been remarked that the peculiar metapterygo-parasphenoidal articulation of *Osteoglossum formosum* has no parallel in any other Teleostean fish, but it is nevertheless interesting to remark that an essentially similar mechanism is to be found in *Lepidosteus osseus*. In this Ganoid the basicranial articular surface for the metapterygoid is formed in part by a lateral outgrowth from the parasphenoid, and partly also by a descending process from the adjacent portion of the prootic, the former process forming the inner, and the latter the outer half of a transversely-elongated condyle provided with smooth, rounded, anterior and ventral surfaces. In his valuable paper on the "Development of the Skull in *Lepidosteus osseus*" (Phil. Trans. Roy. Soc. 1882) the late Professor Kitchen Parker refers to these condyles under the name of "basipterygoid processes," and describes them as being ossified by the alisphenoids. It is difficult, however, to see how this can be the case, at any rate from an examination of the adult skull. The processes in question certainly seem to be formed to an equal extent by the parasphenoids and the prootics, and are widely separated from the alisphenoids. The connection between the proximal elements of the hyoid arch and the corresponding bones of the mandibular arch is neither so intimate nor so rigid as in *Osteoglossum*; but, on the other hand, the metapterygoid, quadrate, pterygoid, and mesopterygoid bones are very firmly and rigidly united together by overlapping sutures. The metapterygoid (see Parker, *loc. cit.* plate 37. fig. 4, *mt.pg.*) is inclined obliquely downwards and forwards, so that the long axis of the bone makes an acute angle with the anterior section of the skull. The upper or cranial extremity of the bone is furnished with a transversely disposed concave surface for articulation with the condyle provided for it by the parasphenoid and prootic. The palato-pterygoid series consists of a relatively small mesopterygoid, which overlaps the dorsal borders of the pterygoid and quadrate bones; and an exceptionally large pterygoid, firmly applied posteriorly to the inner surfaces of both the metapterygoid and the quadrate, and gradually tapering to a thin, flexible, splint-like anterior portion. The latter part of the pterygoid (see Parker, *l. c.* plate 37. fig. 3, *pg.*) forms part of the slender rostral portion of the skull, and is situated between the parasphenoid (*pa.s.*) and vomers (*v.*) mesially, the superficial palatine (*pa.*[1]) and the segmented maxilla (*mx.*[1])

externally, and the frontal (*f.*) and ethmo-nasal (*et.n.*) bones above. The bones forming the lateral portions of the rostrum or snout—that is, the pterygoid, the superficial palatine, and the divided maxilla—are firmly connected together, but their connection with the mesial elements of the rostrum—the parasphenoid, vomers, and ethmo-nasals—is loose and ligamentous. The usual ethmo-palatine articulation is apparently altogether wanting in *Lepidosteus*; but the necessary lateral mobility of the palato-pterygoid series in front is secured, (i.) by the flexibility of the thin anterior portion of the pterygoid, and (ii.) by the loose ligamentous connection which has been described as existing between the palato-pterygoid series, including the maxillæ, and the mesial bones of the beak. The place of the normal ethmo-palatine joint is apparently taken by a secondary articulation furnished by a smooth oval surface on the inner side of a preorbital process of the frontal and a similar facet on the superior border of the pterygoid. It may be concluded, therefore, that, as in *Osteoglossum*, the palato-pterygoid series of bones are capable of more or less extensive lateral movement as a rigid whole on the metapterygo-parasphenoidal and the pterygo-frontal articulations, and, further, that such lateral movements are accompanied by the alternate approximation and separation of the two pterygoid bones in the mesial line of the oral cavity.

As regards the character of the teeth supported by the oral bones, *Lepidosteus* differs considerably from *Osteoglossum*. Apart from the acutely pointed teeth in the maxillæ, there is a series of similar but much smaller teeth in the superficial palatines, and also a number of closely-set denticles on the vomers and on a limited area of the oral surface of each pterygoid. These teeth, however, can only be of service in the vertical movements of the ordinary jaws, and even in the case of the pterygoid teeth it is obvious, from their position, size, and mode of implantation, that they can have no functional significance in connection with the lateral mobility of their supporting bones. It is possible that, as in *Esox*, the lateral mobility of the palato-pterygoid bones and the maxillæ is simply to admit of the lateral expansion of the jaws when seizing relatively large prey; but although this may be one of the advantages which the fish derives from this mechanism, the probability that the partially swallowed prey may be subjected to a process of crushing in the oral cavity by the lateral movements of the pterygoids must, nevertheless, not be lost sight of. It may also be remarked that the latter suggestion is strongly supported by the fact that the superior or inner edges of the two pterygoid bones are capable of being brought into actual contact in the median line of the mouth-cavity for a considerable portion of their length.

There is another interesting feature in which *Lepidosteus* resembles *Osteoglossum*, and that is the structure of the "tongue." In the Ganoid the floor of the mouth is elevated to form a well-marked, elongated, and somewhat strap-shaped "tongue," which